

# AN ORIGINAL METHOD FOR NON-INVASIVE GLUCOSE MEASUREMENT : PRELIMINARY RESULTS

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**Abstract**-This paper presents first results obtained using a novel approach for non-invasive measurement of glucose content. We use a network analyzer, which is used to measure T/R, the modulus of the Transmission to the Reference signal. The under-test solution is placed in the center of a bobbin and plays the role of the self-inductive core. The variation of the "self-inductive medium-core" varies the mutual inductance of the bobbin. We use an electromagnetic signal at a small frequency band about 45 MHz. We have arrived to a measurement about 0.2 g/liter and the results for the temperature influence on the glucose solution are also presented.

**Keywords** - Non-Invasive, Glucose measurement, Diabetes, Impedance

## I. INTRODUCTION

Various methods for monitoring of the glycemia exist [1, 2, 3, 4, 5, 6]. We can generally classify these methods in three categories:

- Methods invasive,
- Methods semi-invasive,
- Methods non-invasive,

There are numerous existing methods for the non-invasive detection and monitoring of biologically significant compounds in a subject. Typically, such methods measure the effect of the compound on the absorbance, reflectance or transmittance of non-ionizing radiation that illuminates a portion of the subject. Despite considerable progress, however, until now truly non-invasive glucose monitor in blood are not a reality.

Our work is to develop a noninvasive simple method for measurement of the glycemia. The glucose molecule reacts as it is exposed to various wavelengths of electromagnetic energy. The basic idea is to find and analysis the correlation of the physiological parameters signatures. These parameters are

acquired by emission-reception of a non-ionizing signal.

We present, in this paper, the method as well as the preliminary results of a noninvasive method for glucose level measurement. The results for the temperature influence on the glucose solution are also presented.

## II. HARDWARE AND METHOD

Our goal is to obtain an original method which allows us the measurement of the blood glucose level by a noninvasive electromagnetic method, without blood test or use lancets; therefore without blood extraction. In this stage we have used HP 419A as a network analyzer, which is used to measure T/R, the modulus of the Transmission signal to the Reference signal or incident signal (figure 1). The solution is placed in the center of a bobbin and plays the role of the self-inductive core. The variation of the "self-inductive medium-core" varies the mutual inductance of the bobbin. The variation of mutual inductance varies the Transmission signal to the Reference signal. Thus modification of the glucose content in the medium leads us to a modification of the transmission frequency response (T/R).

This method, which uses an electromagnetic signal at a small frequency band about 45 MHz, makes it possible to optimize the detection of the presence of glucose in water. Preliminary measurements were used on the one hand to determine the frequency of resonance which reacts better with the medium, and on the other hand to characterize the sensor. Finding an optimal frequency, improvement of the sensor sensibility and resolving of the additional problems such as shielding made it possible to improve the sensitivity of our measurement.

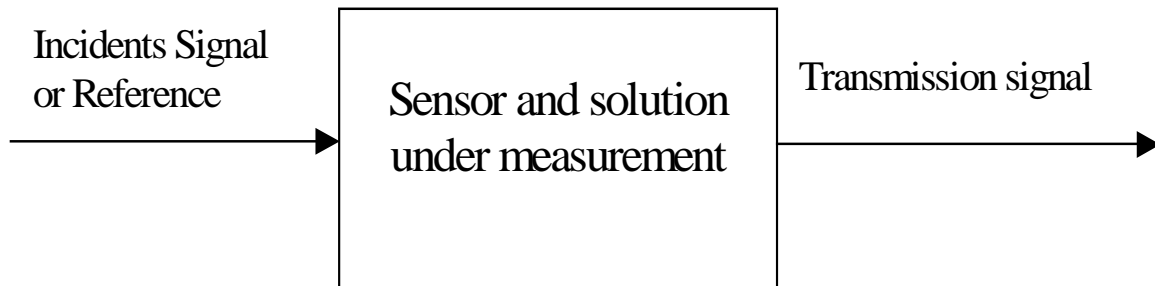


Figure1: Principle of measurement

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### III. RESULT AND DISCUSSION

A series of measurement on water initially brought us to a reliable precision of glucose level lower than 0.2 gram/Liter (g/l). The preliminary result was detection of the presence of glucose in water. Then, work consisted in improving the sensitivity of the sensor so that to enable us to measure the rates of glucose level in the normal range variation, (0.6 g/l < glucose level < 1.2 g/l).

Curve of figure 2 shows the evolution of the modulus of the Transmission signal to the Reference signal (T/R) according to the glucose concentration. These measurements were taken in the frequency range of 44.775- 44.875 MHz. We can note the linear relation that exists between the modulus of T/R and the glucose level. We have done a series of test (here 11 series) and we have measured T/R in the same glucose concentration (in a constant temperature 21°C). After that we calculated in each glucose concentration point the mean value (M) and standard- deviation ( $\sigma$ ). Figure 3 demonstrates these two values as a function of glucose concentration. We preferred to make pass the line through points (least square) that give us a precision better than 0.2 gram/liter. These series of test also show the reproducibility of our measurement. We also studied the influence of the temperature to the measure of the glucose concentration.

Using taken measurements leads us to the curve in figure 4 that shows the variation of these measurements were taken for a constant concentration of glucose, fixed at 2 g/l. We have done the same measurement in different glucose concentration thus we have the influence of the temperature on the glucose level measurement modulus of T/R according to the temperature. This influence being well defined by a simple relation, it will be thus easy for us to compensate this effect by an adequate signal processing.

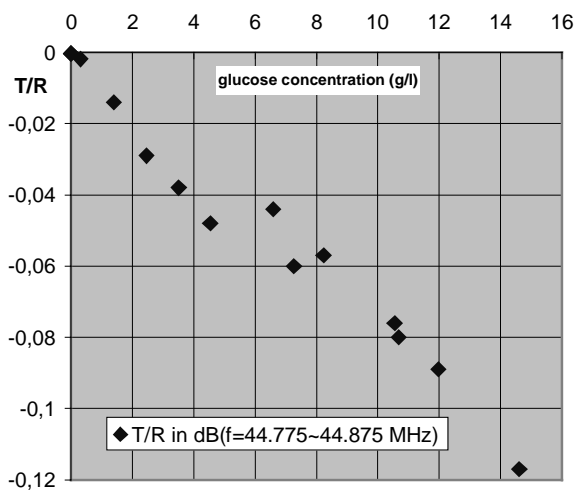


Figure 2 :Modulus of theT/R ratio as a function of glucose concentration .

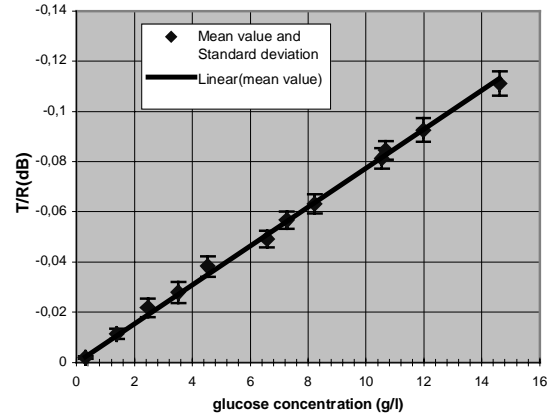


Fig 3:Mean value and Standard deviation of T/R

### IV. PERSPECTIVE AND CONCLUSION

These preliminary results encourage us to continue our work as a different method rather than the use of the infrared or different spectroscopy method and to continue to improve our sensor sensitivity.

This feasibility work forms part of a total project whose objective is the realization of integrated prototype equipment. For that, a specified number of studies are considered like a series of blood glucose level measurement. That consists in two types of measurements: static and dynamic. In these studies, the influence of the temperature, salinity of the solution and also flow rate of the solution in the dynamic case will be developed in order to compensate their effects.

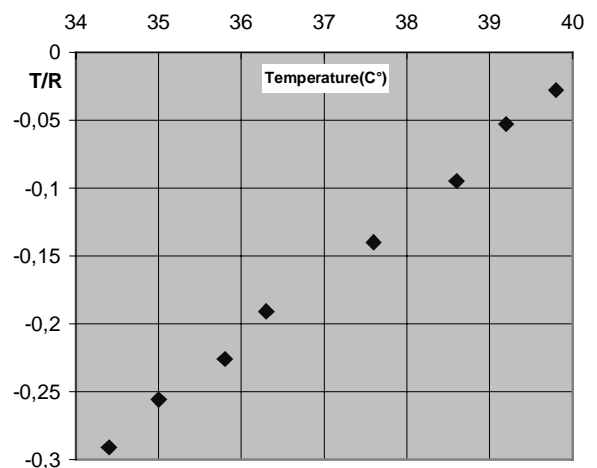


Figure 4: Modulus of the T/R in dB as a function of temperature (f=44.762~44.875 MHz).

#### REFERENCES

- [1]- Wilkins, E and al. "Principles and fundamentals of glucose monitoring", Diabetes mellitus: A fundamental and clinical text. Philadelphia, PA: Lippincott-Raven Publishers. 1996. p. 443-451.
- [2]- Klonoff, DC, « Noninvasive blood glucose monitoring ». Diabetes Care, 1997;20:433-437.
- [3]- H.M. Heise, "Near-Infrared Spectrometry for in vivo Glucose Sensing" in Biosensors in the Body continuous in vivo Monitoring, ed. by D.M. Fraser, John Wiley, Chichester, 79-116 (1997).
- [4]- Heise, H. M.; Marbach, R.; Koschinsky, Th.; Gries; F. A. « Noninvasive blood glucose Sensors based on Near-Infrared Spectroscopy. » Artif. Organs 1994, 18, 439-447.
- [5]- Kajiwar, K., Uemura, T., Kishikawa, H., Nishida, K., Hashiguchi, Y., Uehara, M.. « Non invasive measurement of blood glucose concentrations by analysing Fourier transform infra-red absorbance spectra through oral mucosa. » Med. & Biol. Eng. Comput. 31, S17-S22 (1993).
- [6]- David C. Klonoff. "Mid-Infrared Spectroscopy for Non invasive Blood Glucose Monitoring" The Lasers & Electro Optics Society (LEOS) Vol. 12 N° 2 April 1998. Page 13-14